Role of nutrition and intestinal adaptation in weanling pig health

Douglas Burrin
USDA-ARS, Children’s Nutrition Research Center, Houston, TX, USA

Summary
The growth rate of the pig is most rapid during the neonatal and weaning periods. Nutrition and gastrointestinal function play a critical role in the survival, health and growth of the young pig during this transition from suckling to weaning. The high metabolic rate and cellular turnover of gut tissues result in substantial first-pass utilization of dietary nutrients, especially amino acids, to maintain gut function. The changes in the diet composition and gut microbiota after weaning are associated with increased gut growth and metabolism, which may limit the systemic availability of dietary nutrients. Strategies aimed at optimizing gut metabolism and supplementing key gut-nutrients in support of gut function may improve growth.

Early gut development and nutrition
The neonatal and weaning phases occupy critical periods of postnatal growth and development in commercially reared pigs. The relative rates of growth are higher during the neonatal period than at any time during postnatal life. More importantly, however, is that during the neonatal and weaning phases, the survival, health and subsequent growth rate of young pigs depends on their ability to adapt physiologically to significant changes in nutrition and the environment. Critically to this adaptation process is the development of the gastrointestinal tract, particularly digestive, absorptive and immune function. Nutrition is a key determinant in the functional development and growth of the gastrointestinal tract.

The gastrointestinal tract of the piglet increases nearly three-fold between birth and two weeks after weaning, increasing from 2% to 6% body weight. A major stimulus for gut growth at birth is the initiation of suckling or enteral nutrition. Enteral nutrients have a major anabolic effect on the neonatal gut, but growth factors present in sow’s colostrum and milk may also have trophic effects. Weaning is the second major milestone in gastrointestinal growth in the developing piglet. Nutrition plays a central role during weaning, first by limiting gut growth due to reduced feed intake and then providing a major stimulus due to increased dry matter intake and changes in diet composition.

The weaning transition is marked by reduced villus height, increased crypt cell hyperplasia and expansion of the lamina propria cell population. The weight of the colon is increased approximately threefold within seven days after weaning, mainly due to increased fermentation of undigested dietary carbohydrates and fiber. The hyperplasia in the crypt epithelium and lamina propria is thought to be linked to gut hypersensitivity reactions associated with plant proteins in the weaning diet, such as soy glycins and lectins.

The weanling pig is especially vulnerable to pathogenic infection because of the withdrawal of sow’s milk and the increased colonization of commensal gut microorganisms. Pathogenic infection results in an activation of the mucosal immune system and release of proinflammatory cytokines (e.g. tumor necrosis factor “ and interleukins) that have been shown to increase crypt cell proliferation, villus enterocyte apoptosis, and intestinal acute phase protein synthesis.

The concept of gut nutrient requirements
Most swine nutritionists have an extensive knowledge of the nutrition requirements for the pig growth. However, in recent years, the concept of nutrient requirements has evolved to include the needs specifically for the gut. Technical advances have enabled direct estimates of gut nutrient utilization and their impact on whole animal nutrient metabolism in vivo studies in pigs using isotopic tracers and measurements of trans-organ balance of substrates. These and other studies with cultured porcine intestinal epithelial cells have revealed important qualitative characteristics of the metabolic fate of key substrates and the underlying cellular basis for intestinal nutrient utilization.

A major concept that has emerged from studies with young pigs is that non-essential amino acids are major gut fuels, especially glutamate, glutamine and aspartate. In vivo studies in pigs show that roughly 70-80% of the dietary glutamate, glutamine and aspartate is taken up by the gut in first pass and metabolized to CO2. Glucose is also quantitatively an important oxidative fuel for the pig intestine, in absolute amounts; the intestinal utilization of glucose is similar to the combined total from glutamate, glutamine and aspartate. However, the proportional use is lower, such that only ~20-30% of the dietary glucose is metabolized by the gut.

Studies with pigs have shown that the neonatal intestine plays a key role in the metabolism of amino acids involved in the urea cycle, particularly arginine, proline, and ornithine. There is extensive interconversion between these amino acids and the intestine represents an important site of net arginine synthesis in neonatal pigs. Studies in pigs have also demonstrated the extensive metabolism of other essential amino acids, including threonine, lysine, phenylalanine, branched-chain amino acids, and methionine. It is generally considered that the primary metabolic fate of essential amino acids taken up by the gut is incorporation into tissue proteins. However, studies show that extensive irreversible catabolism and oxidation of amino acids occurs in the gut. Moreover, many of these essential amino acids are metabolized to other intermediates involved in intestinal function. For example, threonine is believed to be channeled into mucin synthesis and secreted by goblet cells, because mucin peptides are rich in threonine. Methionine may be converted to cysteine or s-adenosyl-methionine used in polyamine synthesis. Cysteine is used as a precursor for glutathione synthesis and maintenance of mucosal anti-oxidant status. The oxidation of some essential amino acids, such as the branched-chains and lysine, in the gut may be nutritionally significant. The high essential amino acid utilization rate by gut tissues can have a significant impact on the systemic availability for lean tissue growth.

Studies with pigs using isotopic tracers and measurements of trans-organ balance of substrates. These and other studies with cultured porcine intestinal epithelial cells have revealed important qualitative characteristics of the metabolic fate of key substrates and the underlying cellular basis for intestinal nutrient utilization.

Most swine nutritionists have an extensive knowledge of the nutrition requirements for the pig growth. However, in recent years, the concept of nutrient requirements has evolved to include the needs specifically for the gut. Technical advances have enabled direct estimates of gut nutrient utilization and their impact on whole animal nutrient metabolism in vivo studies in pigs using isotopic tracers and measurements of trans-organ balance of substrates. These and other studies with cultured porcine intestinal epithelial cells have revealed important qualitative characteristics of the metabolic fate of key substrates and the underlying cellular basis for intestinal nutrient utilization.

A major concept that has emerged from studies with young pigs is that non-essential amino acids are major gut fuels, especially glutamate, glutamine and aspartate. In vivo studies in pigs show that roughly 70-80% of the dietary glutamate, glutamine and aspartate is taken up by the gut in first pass and metabolized to CO2. Glucose is also quantitatively an important oxidative fuel for the pig intestine, in absolute amounts; the intestinal utilization of glucose is similar to the combined total from glutamate, glutamine and aspartate. However, the proportional use is lower, such that only ~20-30% of the dietary glucose is metabolized by the gut.
order to maximize growth of the whole animal. However, with a new understanding of intestinal nutrient utilization, it is possible to now formulate weanling pig diets with the specific goal of optimizing the growth, function and health of the gut. From the foregoing discussion of intestinal nutrient utilization some of the most promising candidates are glutamine, glutamate and threonine.

**Nutrition and enteric health and function**

A critical factor influencing the growth of weanling pigs is the degree of colonization with commensal and pathogenic microbes. Exposure to these microbes and their toxins can adversely affect intestinal structure and function. The pro-inflammatory stimulus induced by bacteria, endotoxin and cytokines significantly increases the intestinal protein synthesis rate. Studies in sheep show that parasitic infection increases the rate of leucine utilization and oxidation by PDV tissues, thereby reducing the systemic availability of dietary amino acids by 20-30%. Thus, it is likely that the degree of commensal and pathogenic microbial load directly affects the intestinal nutrient requirements, which in turn may consume dietary nutrients and limit growth of weanling pig.

Antimicrobial compounds are fed to weanling pigs in order to suppress the activity of the gut microflora and enhance growth. Antimicrobials are thought to act via four possible mechanisms, a) prevention of infection, b) reduced microbial nutrient use, c) enhanced nutrient absorption, and d) reduced growth-depressing microbial metabolite load. It is generally held that one or a combination of these mechanisms act to diminish the thickness and mass of the intestinal mucosa and associated lymphoid tissue. A critical mechanistic question regarding the site of dietary amino acid utilization in the gastrointestinal tract is whether this activity is associated with the luminal microbes or the cell populations of the mucosa.

Alternative nutritional strategies are being used to manipulate the gut microflora including probiotics, prebiotics, organic acids, spray-dried plasma, and high concentrations of copper and zinc. These approaches have become an increasingly important consideration in swine nutrition, given the evidence of their benefits in animals and humans coupled with the growing concern of antimicrobial resistance. Probiotics and prebiotics are used to induce the colonization of bacteria (e.g. lactobacillus and bifidobacteria) considered to be beneficial for the host. The consequences of these alternative nutritional strategies on gut metabolism and nutrient utilization are poorly understood and warrant further study.

**References**


